

# ARM Water Vapor Research and ARM Site Atmospheric State Best Estimate

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# ARM Water Vapor Research

- ◆ **Special ground-based facilities, including**
  - **Microwave radiometers**
  - **Accurate in situ references**
  - **Raman Lidar**
  - **AERI**
  - **Millimeter Cloud Radar**
  - **Micropulse and Ceilometer Cloud Lidars**
- ◆ **Highlight issues with sondes**
- ◆ **Approach to Best Estimate Atmospheric State**

# ARM *Atmospheric Radiation Measurement Program*

## *In Situ Sensors*

Mailbox Vaisala



60m Tower

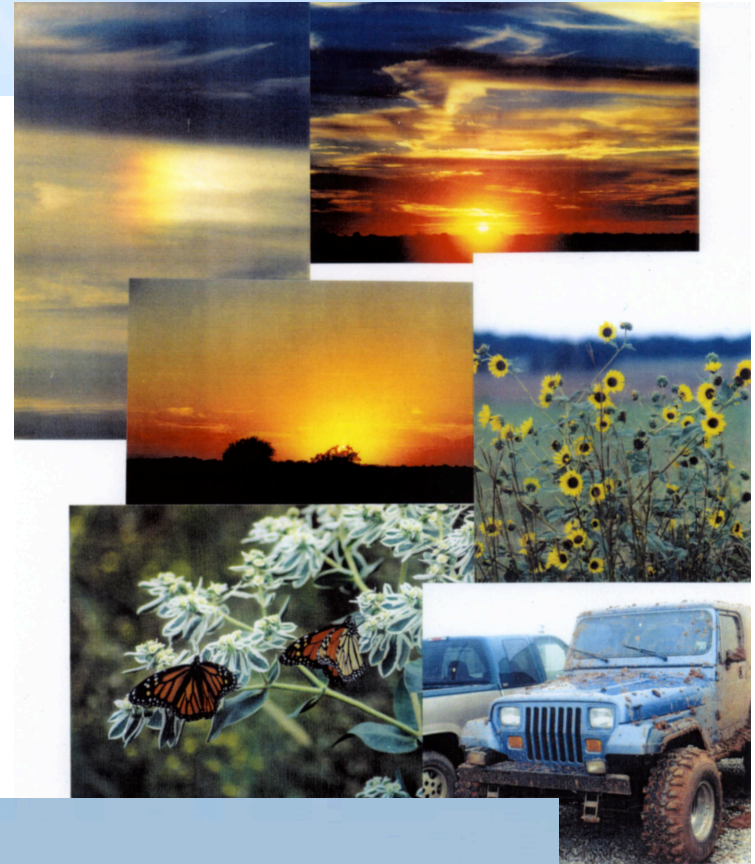


Sonde



## Microwave

ARM MWR



## LIDAR

ARM Raman

NASA Raman

MPI DIAL

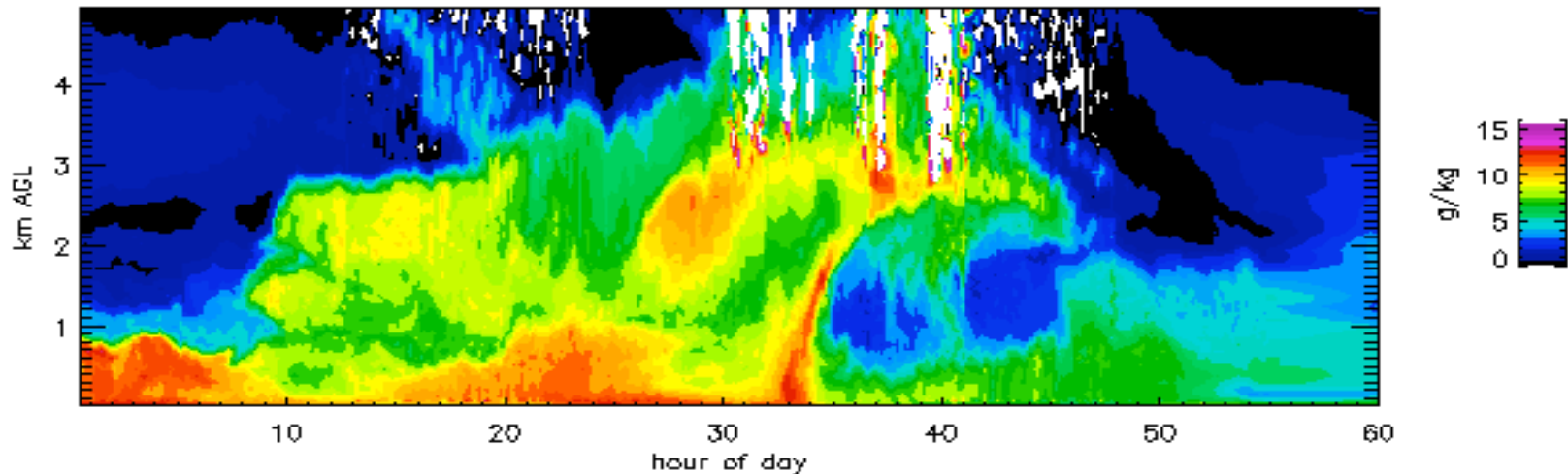


# Raman Lidar (RL)



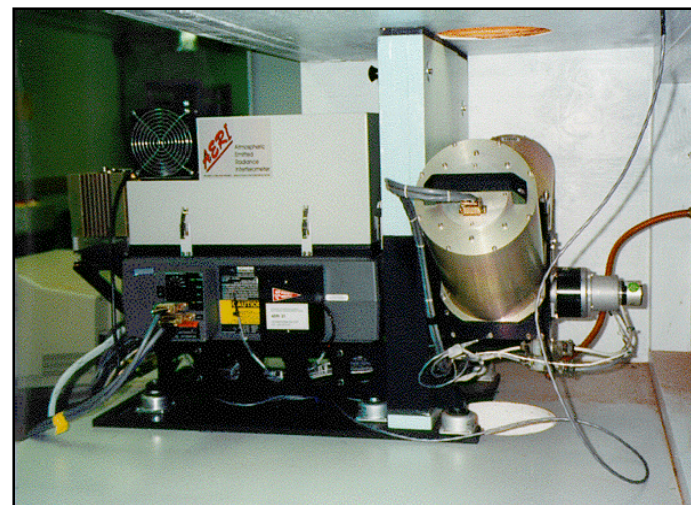
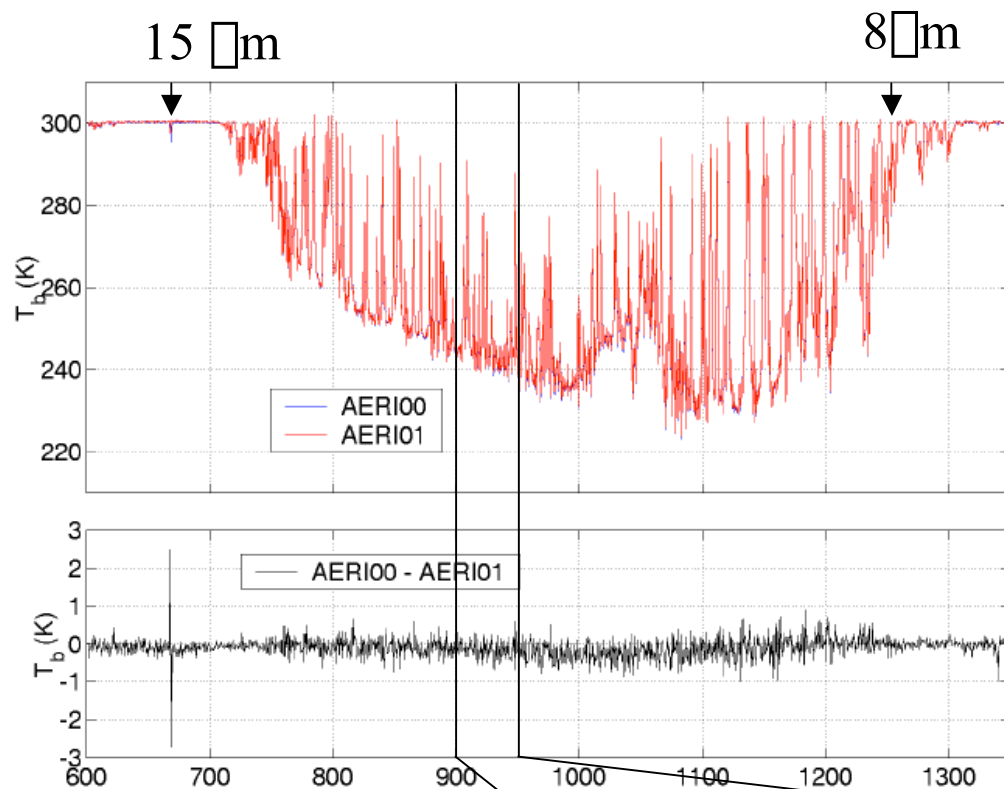
- Automated 24-hour profiling
- Detects water vapor &  $N_2$  Raman scattering, plus elastic scattering
- Products include profiles of
  - (1) water vapor mixing ratio
  - (2) aerosol extinction, backscatter, and optical thickness
  - (3) linear depolarization ratio

Water vapor mixing ratio

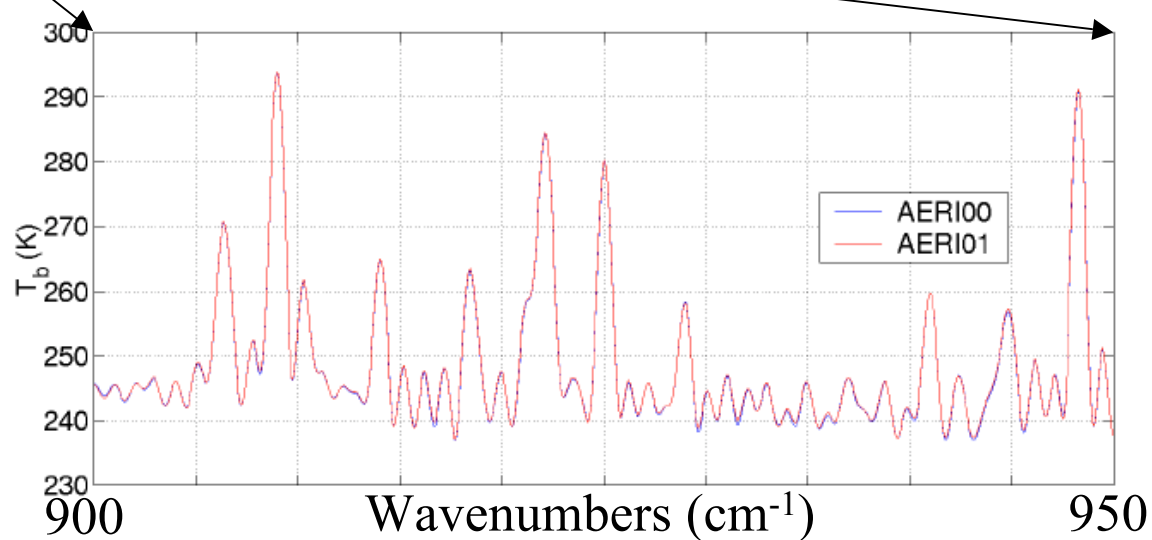




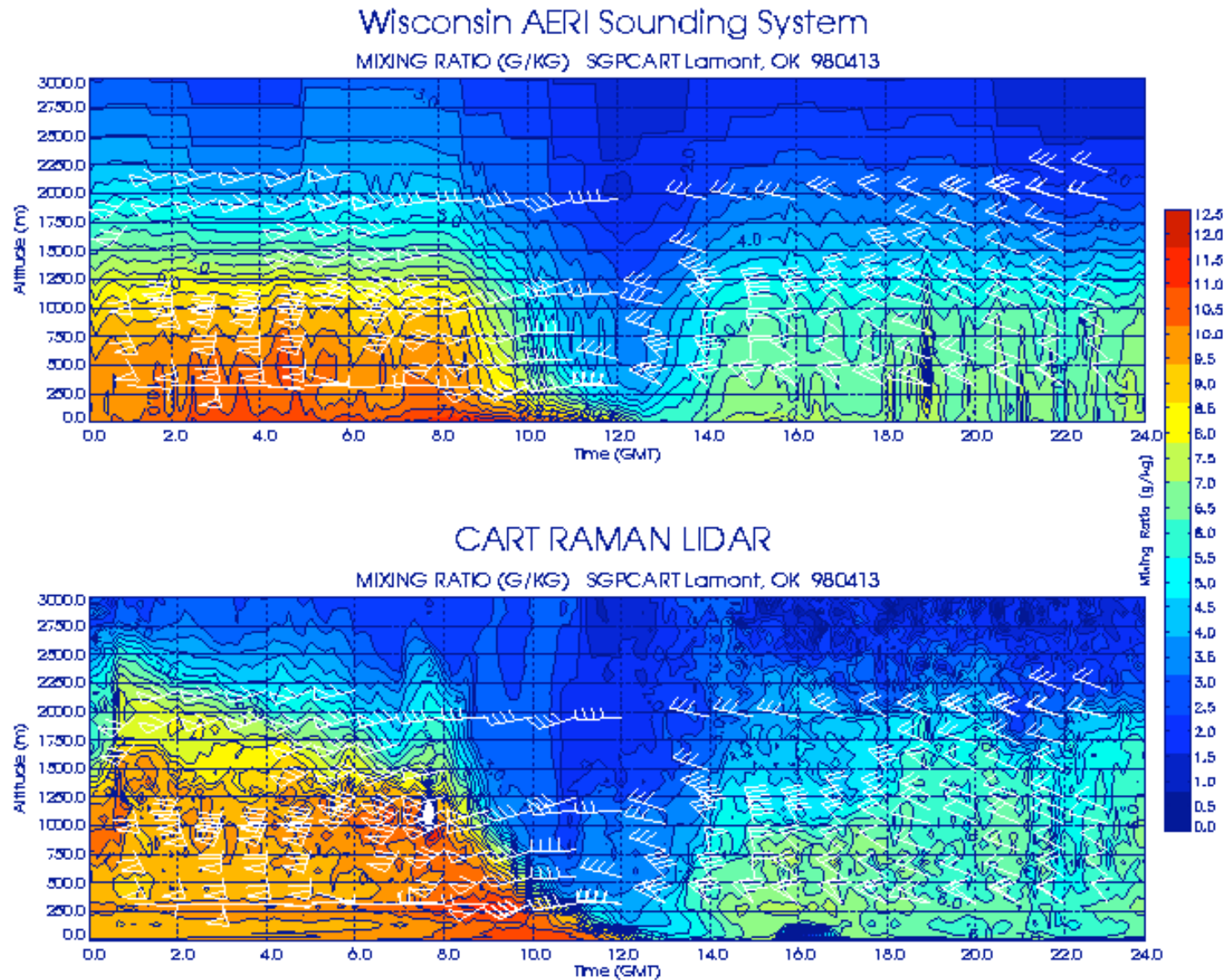
# AERI Spectra



## Brightness Temp Overlay of 2 Observations



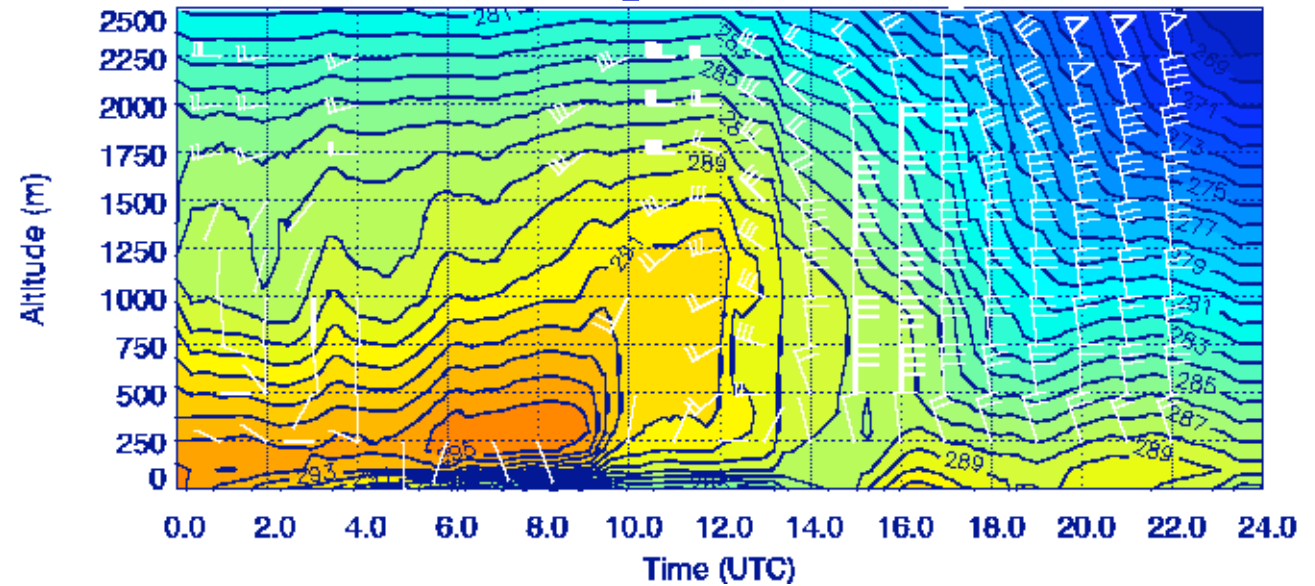
# AERI Water Vapor Mixing Ratio compared with Raman Lidar



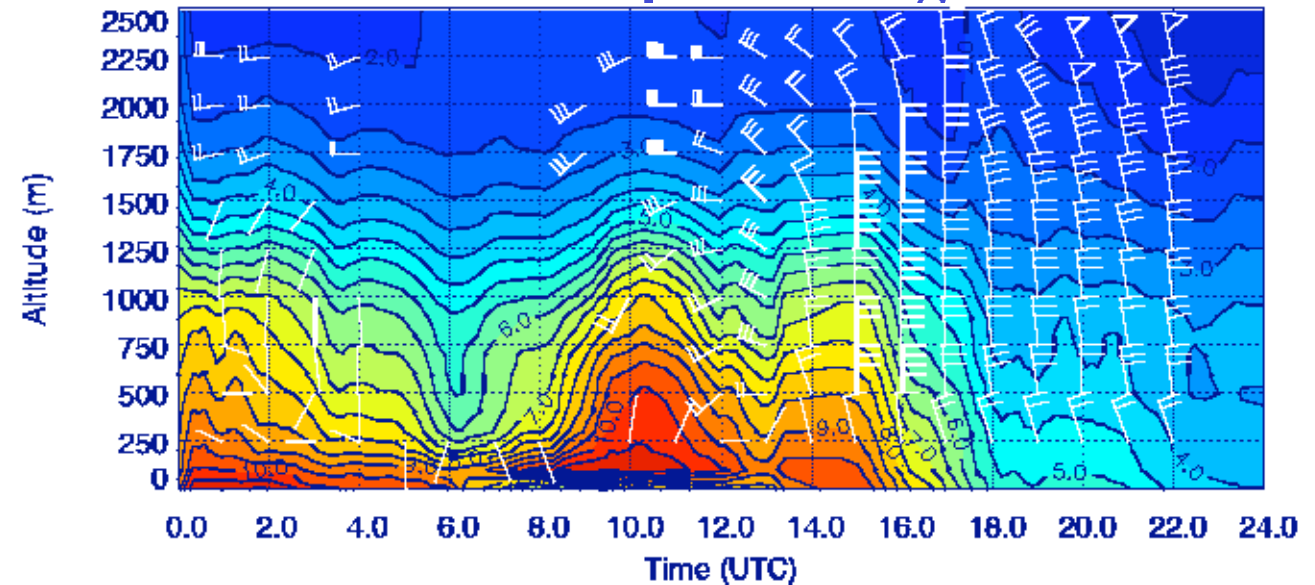
# AERI Retrievals

Cold Front  
Passage,  
Lamont, OK  
7 April 2000

## Temperature



## Water Vapor Mixing Ratio



# ARM Water Vapor IOP's: Background

## ◆ **Motivation:**

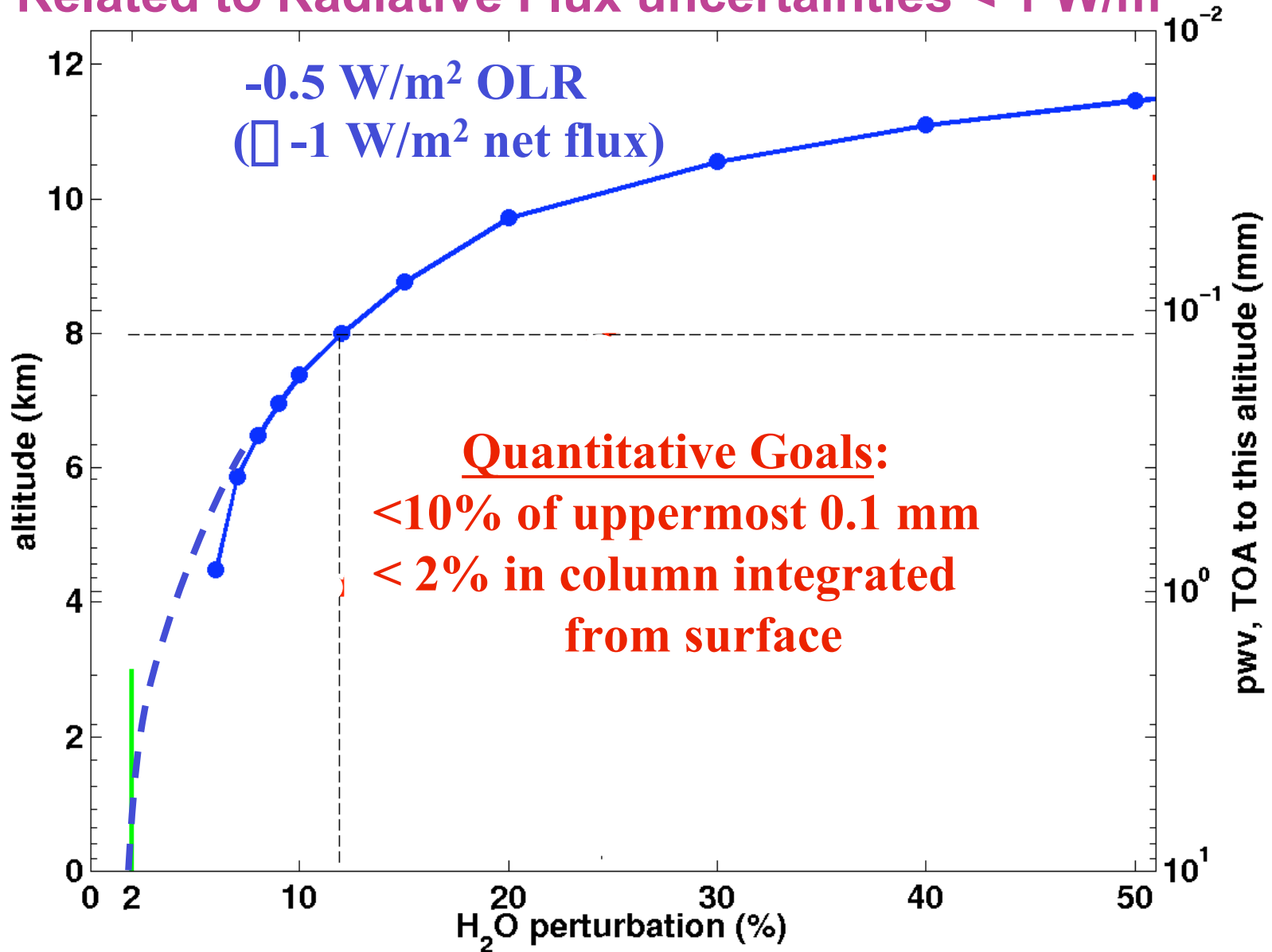
- (1) Lower Troposphere: Line-by-line Radiative Transfer Model improvements from AERI limited by water vapor uncertainties
- (2) Upper levels: Small amounts of water vapor strongly influence emission to space and cooling rates

## ◆ **Goals:**

- (1) Characterize current observing accuracy from Sondes and *In Situ* sensors
- (2) Develop techniques to reduce WV uncertainties (approaching 2% absolute accuracy in the lower troposphere & 10% of upper-most 0.1 mm)



# Water Vapor Uncertainty Goals: Related to Radiative Flux uncertainties $< 1 \text{ W/m}^2$



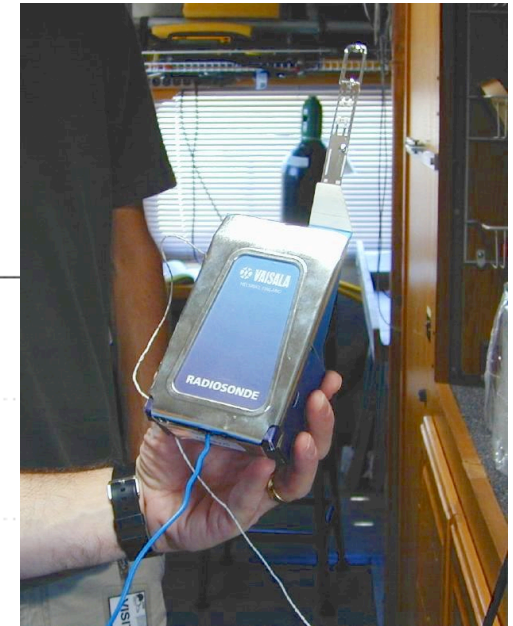
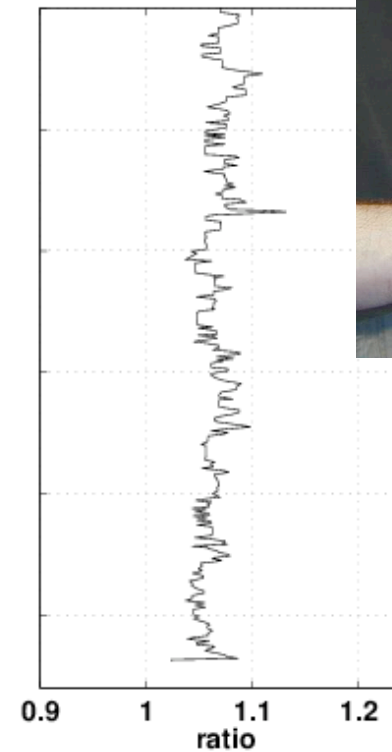
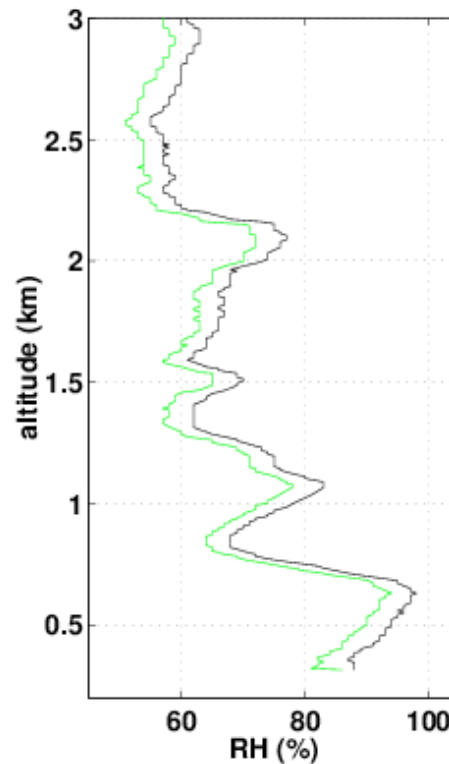
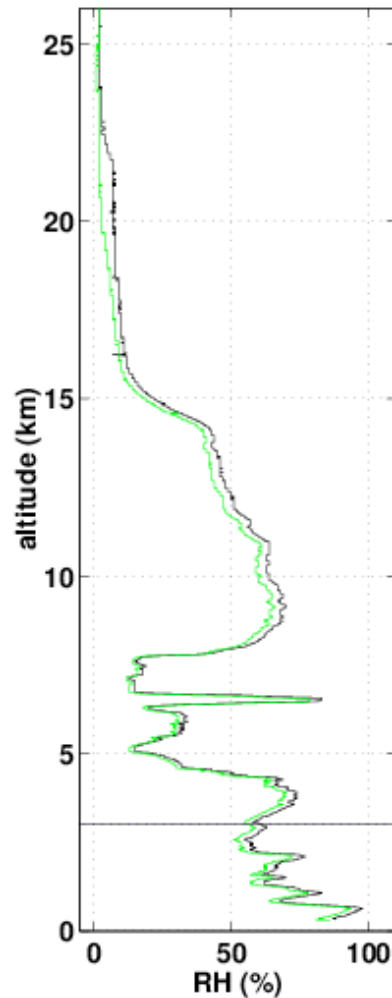
# Vaisala Radiosondes

(RS-80, until RS-90 replacement in 2000)

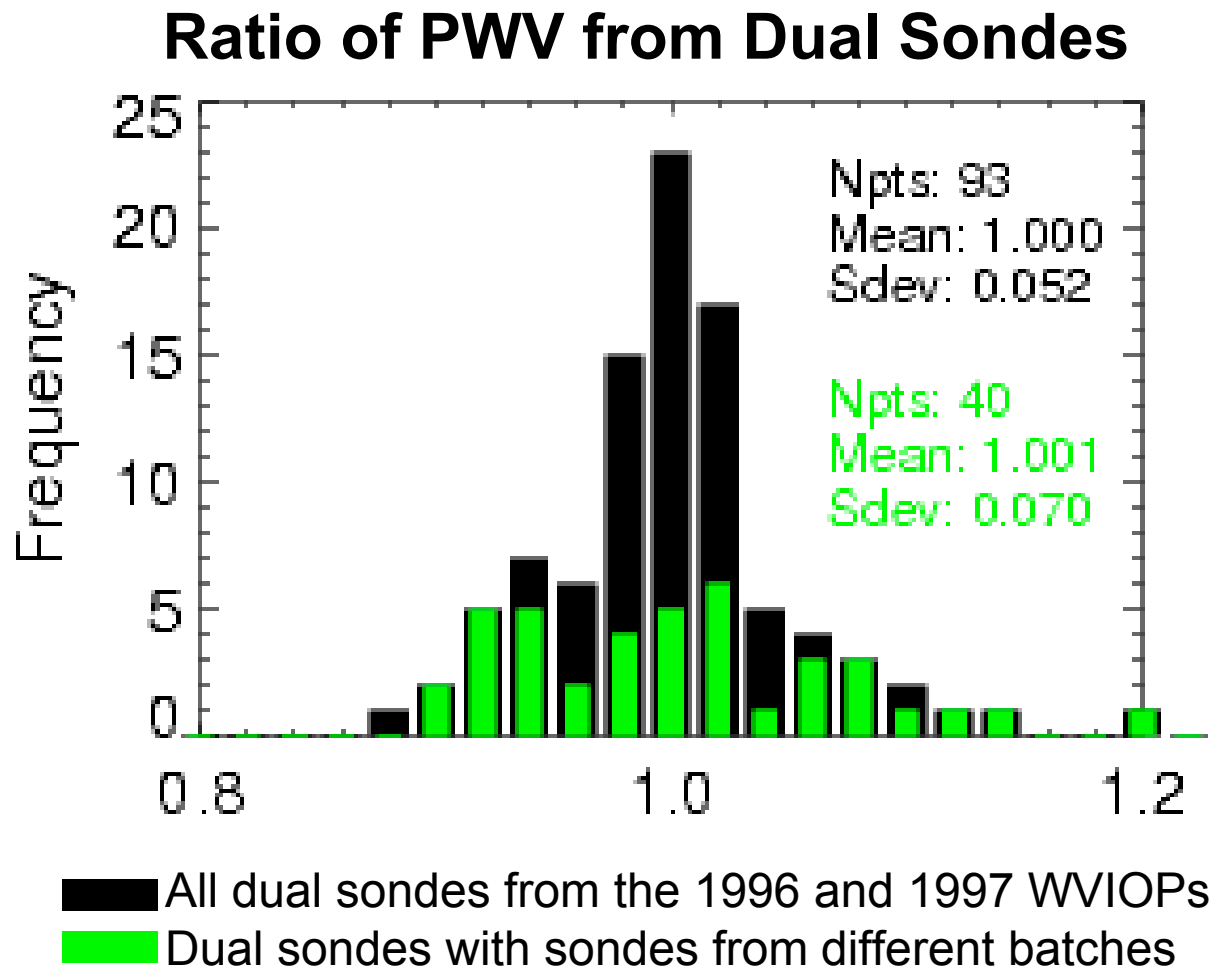
- ARM found large ( $>30\%$  p-p) Sonde-to Sonde scatter that acts like a scale-factor calibration error
- Dry bias (averaging  $\approx 5\%$ ) relative to microwave identified
- Calibration batch-to-batch & diurnal biases identified
- Sonde dry bias also identified by NCAR in TOGA COARE
- Correction developed by Vaisala that removes dry bias, but little effect on scatter & 3% daytime diurnal dry bias
- A stable reference, like the microwave radiometer, is key to reducing scatter to acceptable levels

# Dual Radiosonde Differences:

Dominantly Characterized as  
Scale-factor Calibration Errors!

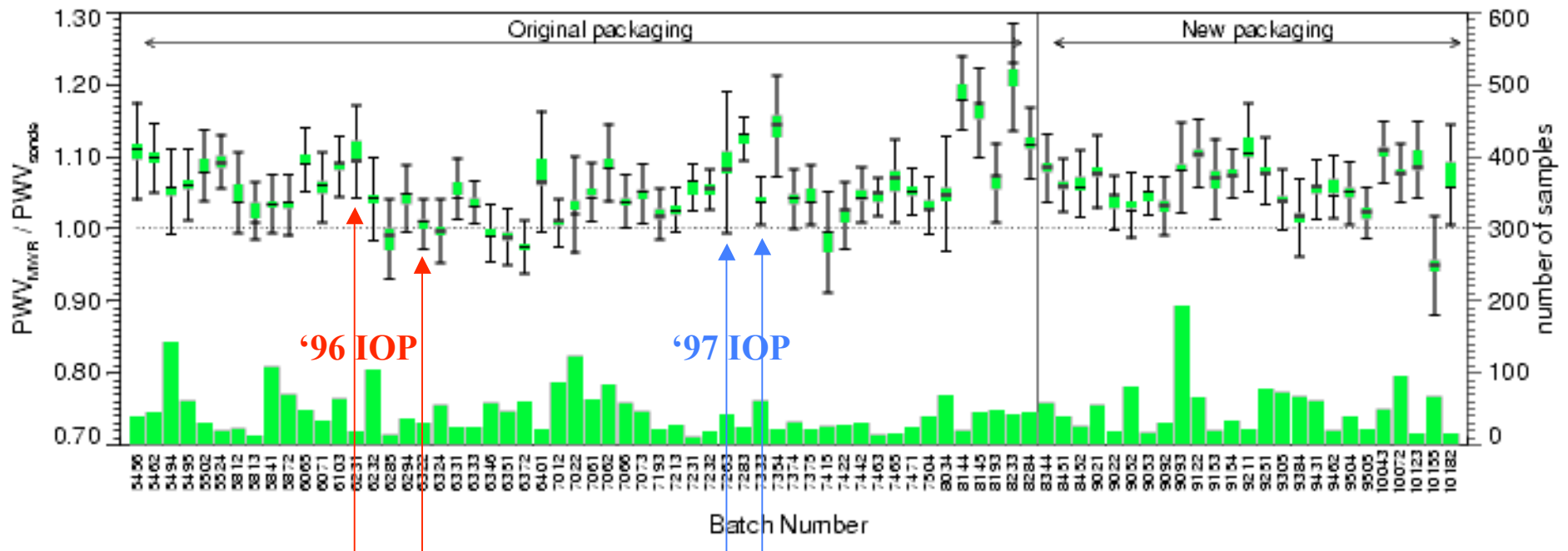


# Dual Sonde Launches Revealed Sonde-to-Sonde Differences of $> 30\%$ p-p





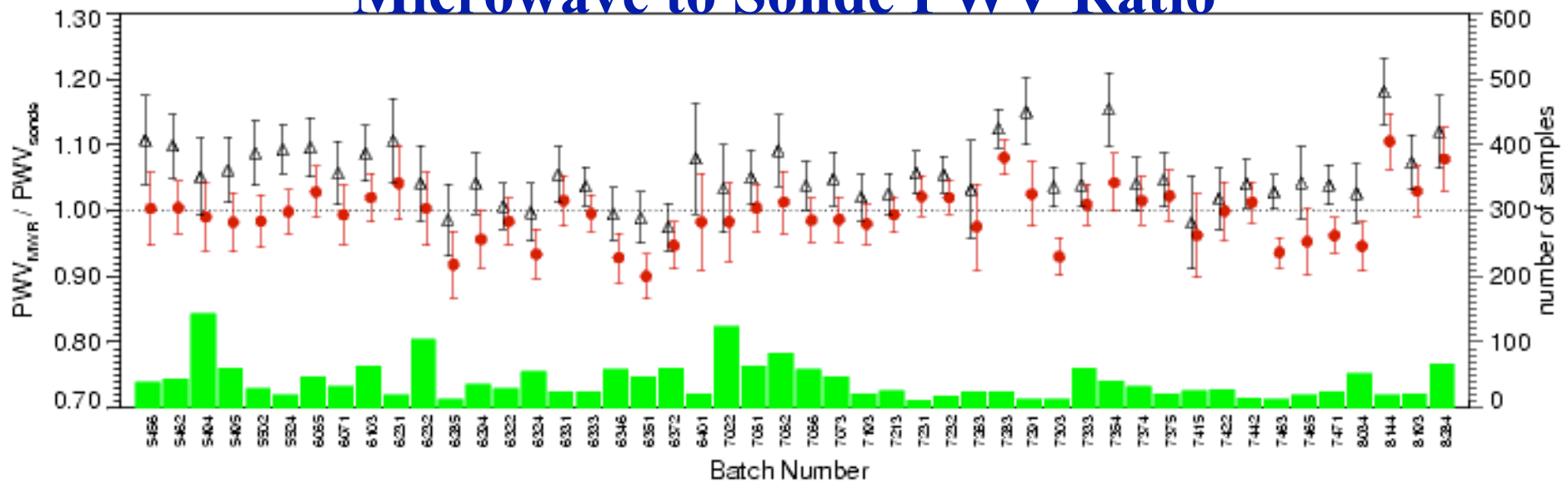
# Ratio of Microwave to Radiosonde PWV



- Microwave ratio for 4 year record shows sonde-to-sonde variability similar to dual sondes
- Displays 5-6% sonde dry bias relative to microwave
- Standard Deviation is about 7% (implies >35% p-p), including significant calibration batch dependence

# Effect of Vaisala Correction (red symbols)

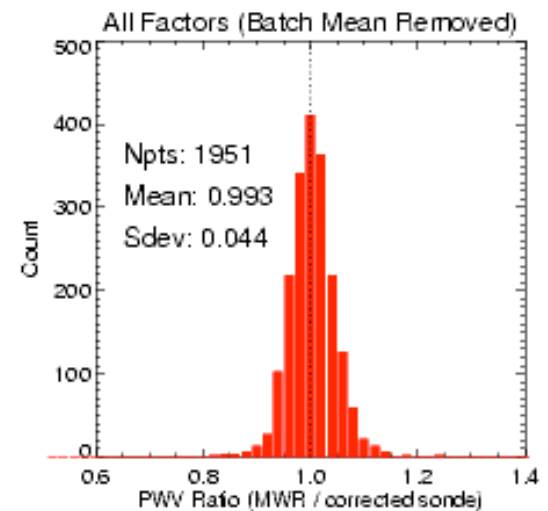
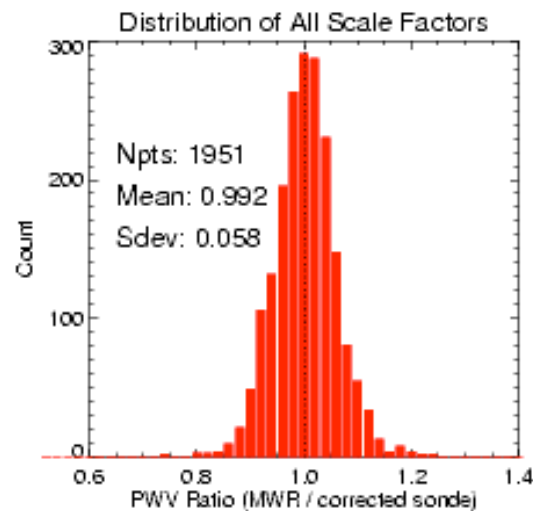
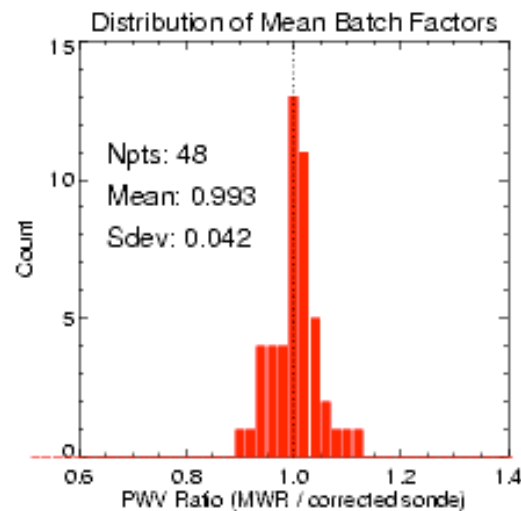
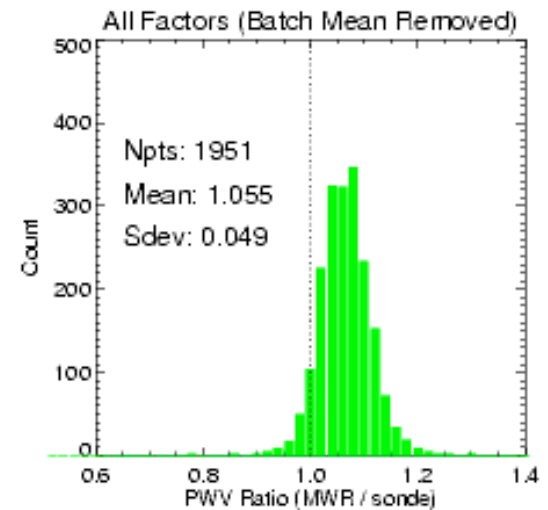
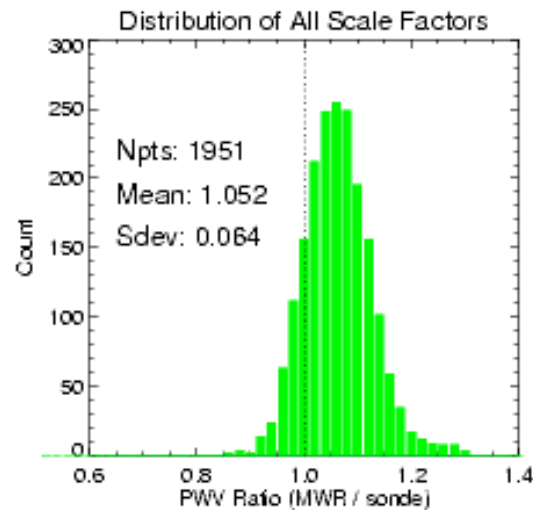
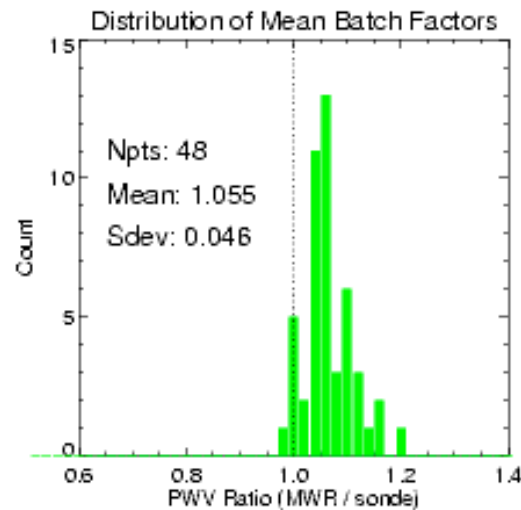
## Microwave to Sonde PWV Ratio



- Sonde 5% mean dry bias eliminated
- Large Scatter, 3-4% daytime dry bias, & Calibration batch dependence mainly unchanged

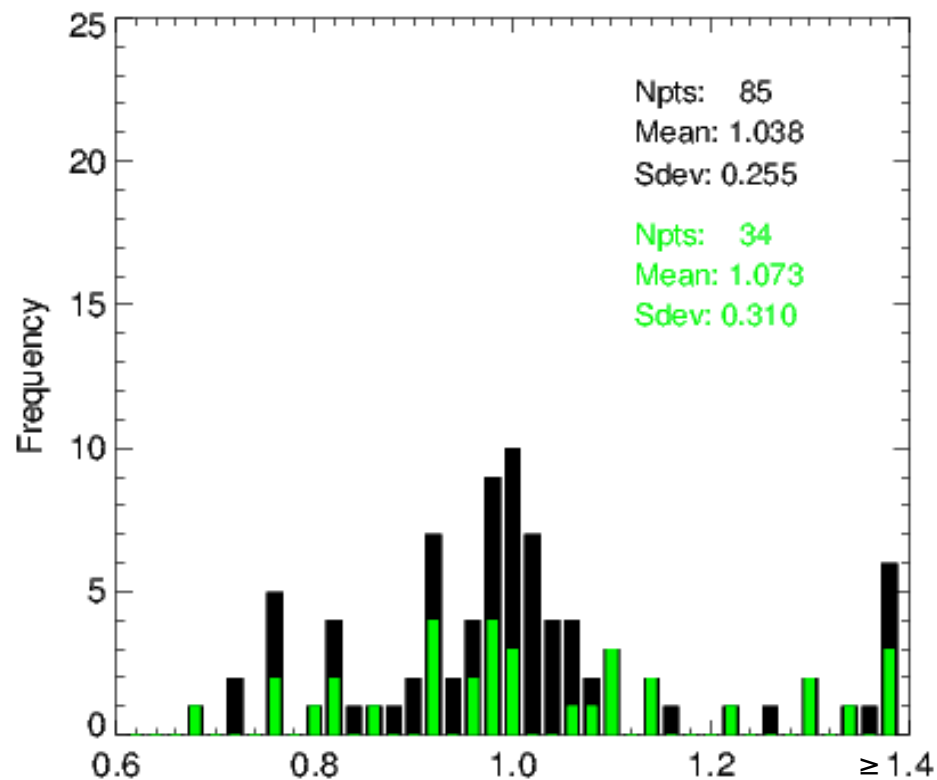
# Analysis of MWR “Scale Factors”

uncorrected and corrected sondes

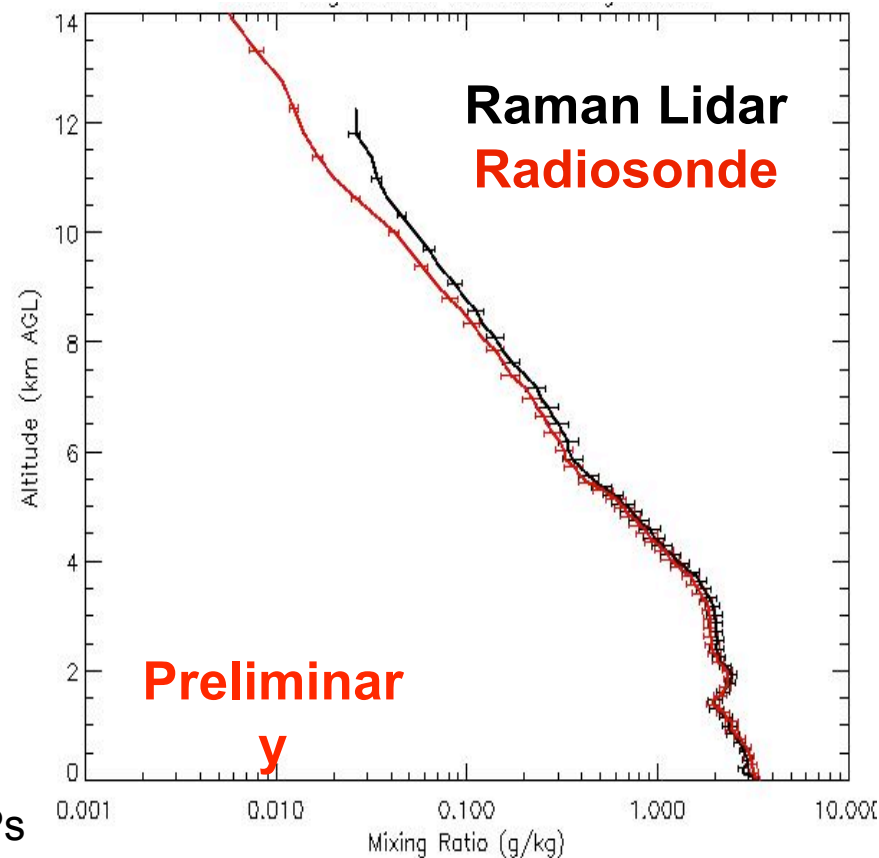


# Upper Level Findings

Ratio of 8-12 km integrated water vapor from Dual Sondes



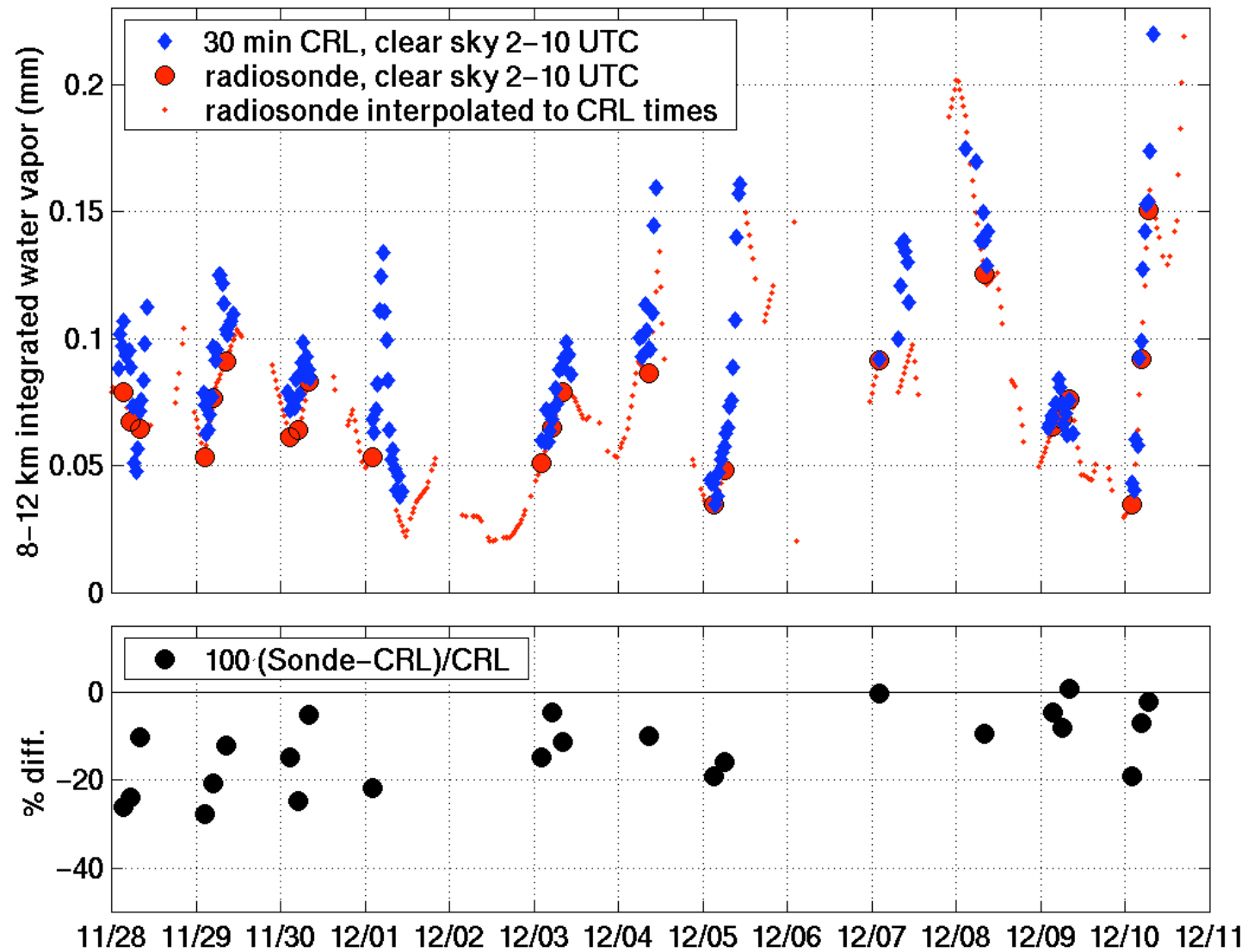
Mean Nighttime profiles during AFWEX



- All dual sondes from the 1996 and 1997 WVIOPs
- Dual sondes with sondes from different batches



# Upper Level Findings

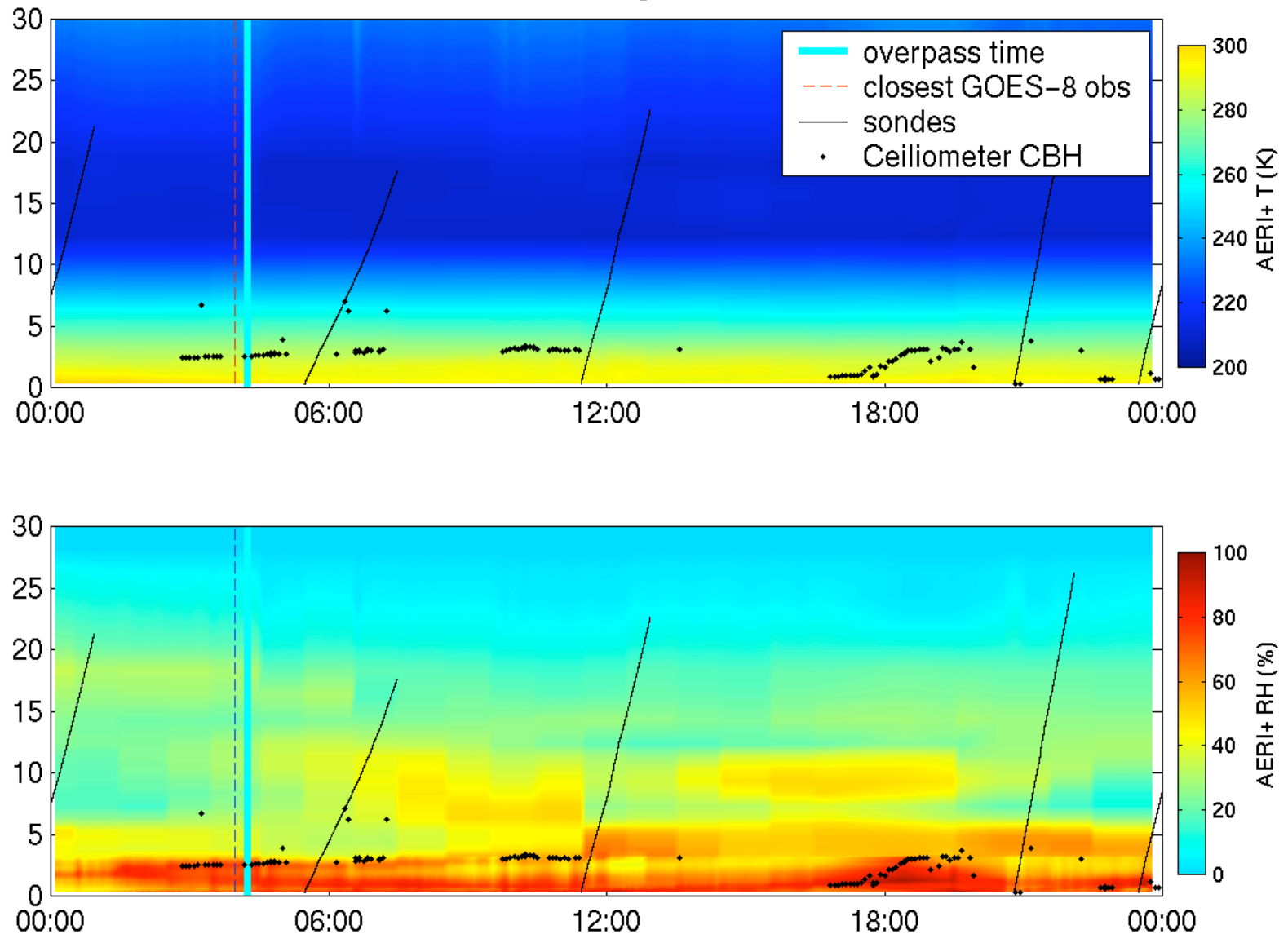


# AIRS ARM Atmospheric State Best Estimate

- Current algorithm for the Southern Great Plains uses: radiosondes, MWR, AERI+ retrieval, Vaisala ceilometer, RUC-2 profiles, GOES-8 retrievals, surface and tower-based *in-situ* sensors, and IRT data.
- Two radiosondes that closely bound one overpass time per day will be launched from all ARM sites for Aqua/AIRS, 3 months per year
- Time interpolation between sondes currently uses AERI + retrieval 10 minute data (clear) or hourly RUC-2 profiles (cloudy)
- Large scale spatial gradients within AMSU FOV accounted for using GOES8 (clear) or RUC-2 (cloudy) profiles
- Upper Tropospheric Humidity (UTH) correction making use of Raman Lidar is under development
- Land surface emissivity estimates from AERI measurements of pure SGP surface types (vegetated and non-vegetated) combined with estimates of the vegetation cover as a function of day of year
- Surface temperature estimates from downlooking (from 10m) narrow-band 10mm radiometer (IRT) at CART site
- Cloud mask and heights provided by Vaisala ceilometer
- Uncertainty estimates will be provided
- Currently working on QC and automation of algorithm for SGP site, then NSA and TWP sites

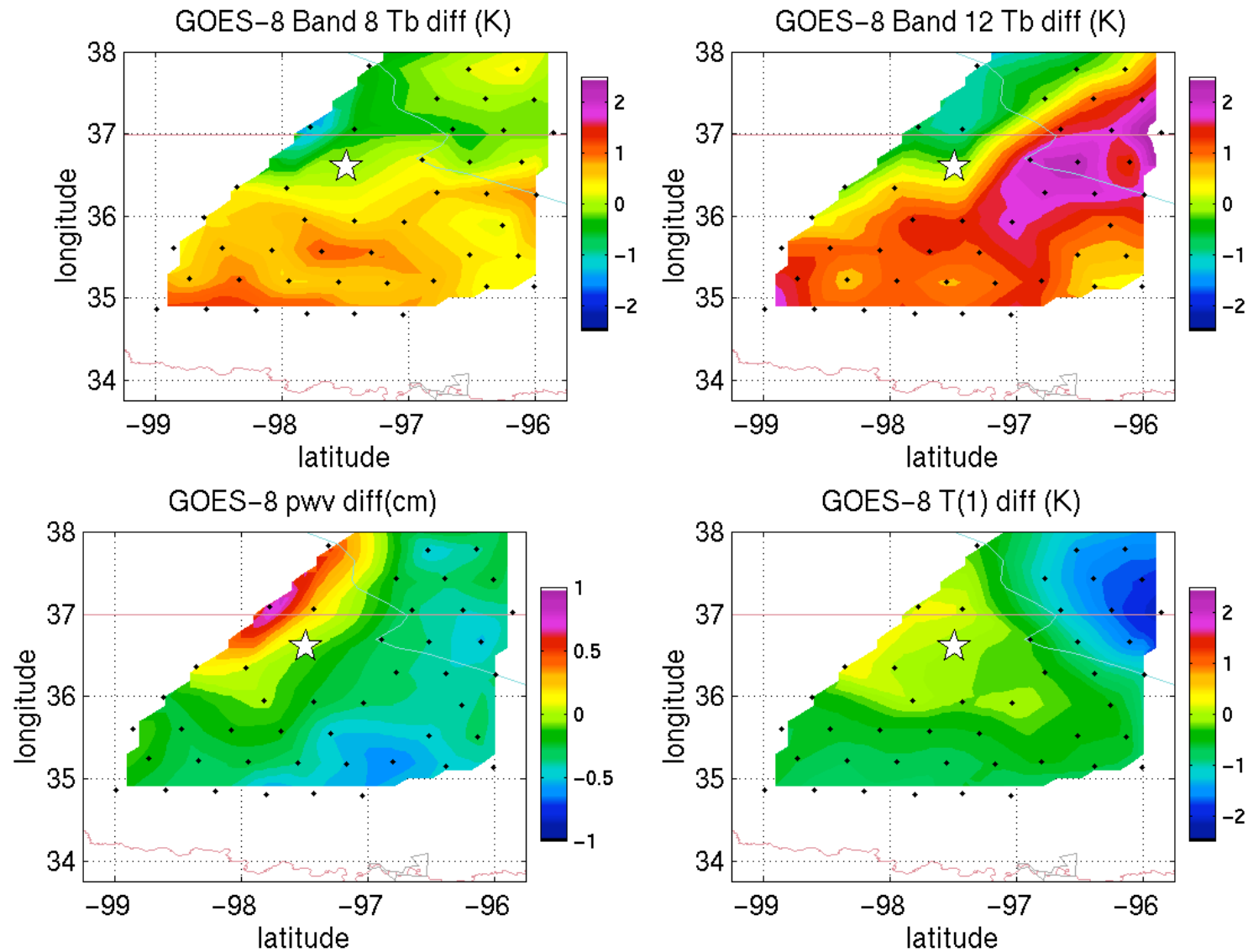
# AIRS ARM Atmospheric State Best Estimate

## AERI+ retrievals for time interpolation between sondes



# AIRS ARM Atmospheric State Best Estimate

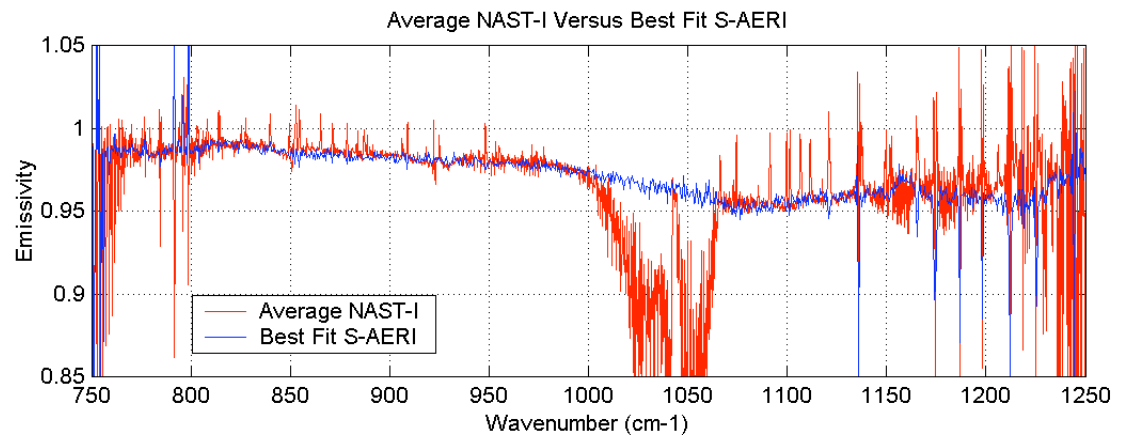
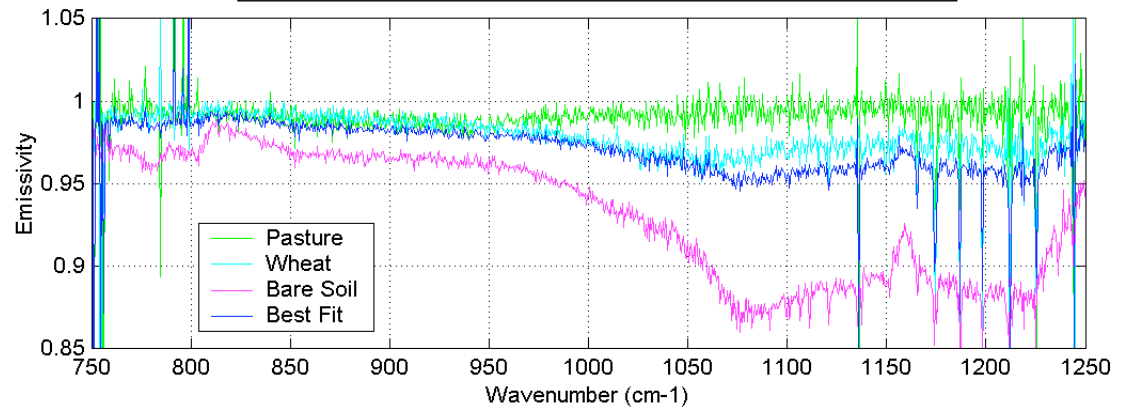
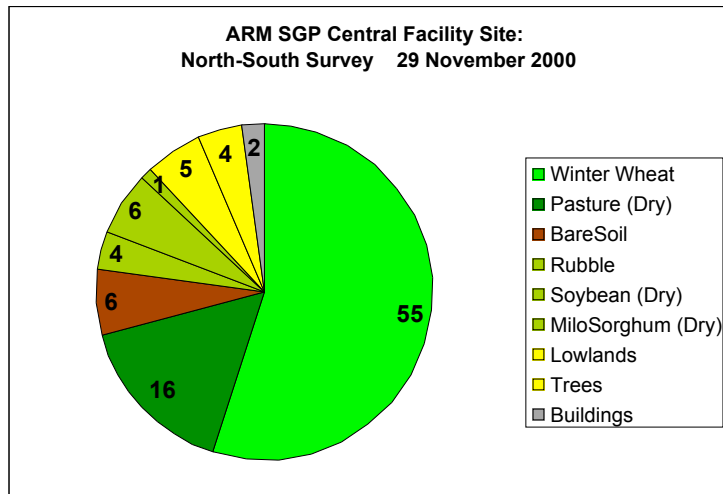
## Spatial gradients





# SurfaceType/Emissivity Survey

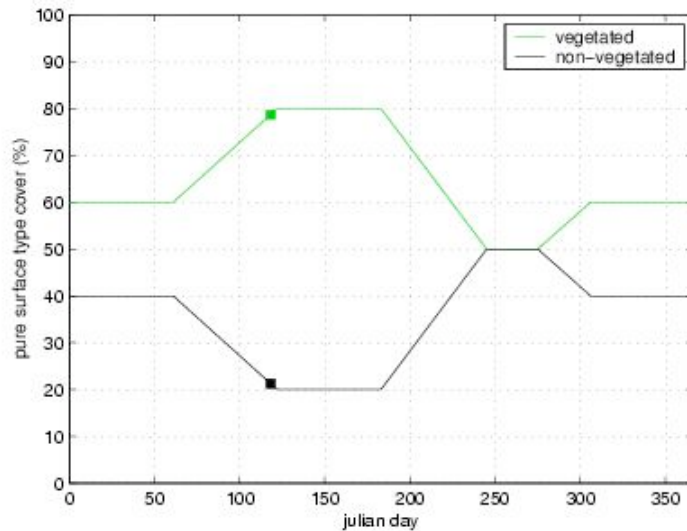
A survey was conducted on Nov 29 to characterize the surface type and spectral emissivity in the vicinity of the ARM SGP Central Facility site.



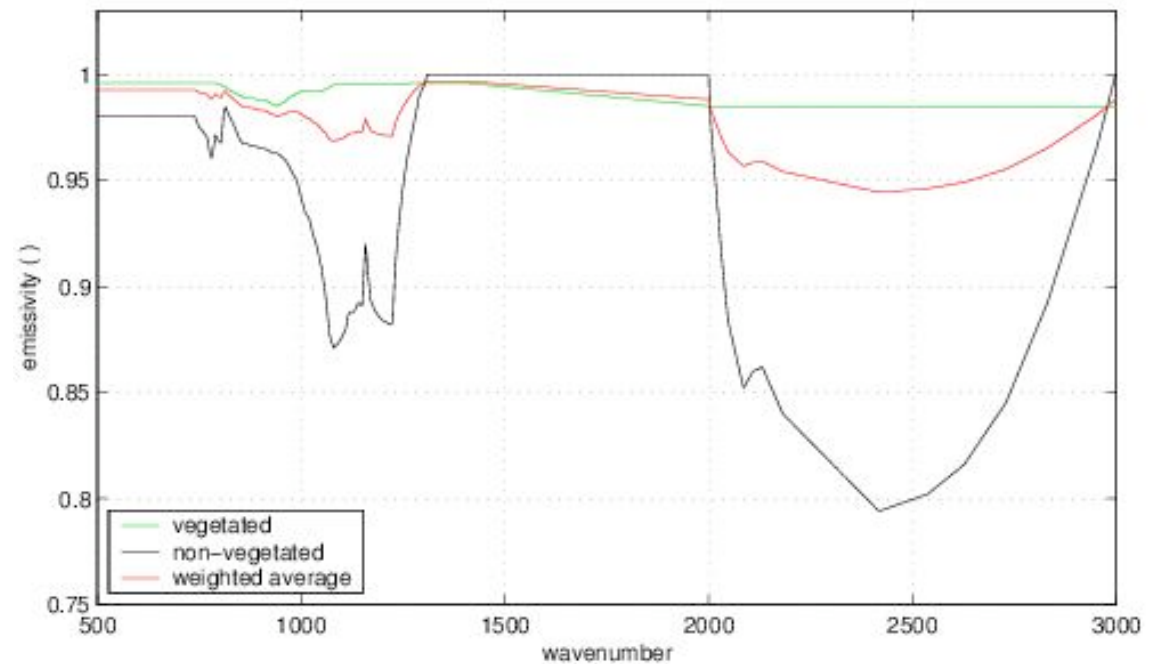
# AIRS ARM Atmospheric State Best Estimate

## SGP Surface emissivity estimate

vegetation fraction  
vs. day of year



Linear combination of bare soil  
and vegetated emissivities



# AIRS ARM Atmospheric State Best Estimate

**15 Dec 2000 SGP overpasses  
at 0807 and 1910 utc**

Raman lidar linear depolarization ratio data  
15 Dec 2000

